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A NEW METHOD FOR THE SOIL MOISTURE MEASUREMENT (MOMIN'S METHOD)

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A NEW METHOD FOR THE SOIL MOISTURE MEASUREMENT (MOMIN'S METHOD)*

Jirō Kubo**

ABSTRACT. A description is given of a new method of measuring soil moisture utilizing thermal conductivity. The equipment is described, and it is concluded that this method is satisfactory for routine measurements at a fixed location.

1. INTRODUCTION

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There are various methods [1] of measuring the soil moisture, but the standard method of weighing gives the most accurate value today. The other methods have not been developed beyond the experimental stage and entail many difficult problems yet before the adoption of routine measurements.

The engineering group of the industrial meteorological section of the Central Meteorological Observatory [2] has been making observations of the soil moisture, 5 cm and 10 cm deep from the ground surface, daily at 10 o'clock using the weighing method.

Although the weighing method gives the most accurate measurement of the soil moisture, the desiccation of the sample soil requires at least eight hours [3]; therefore, it is not possible to

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**Central Meteorological Observatory.

***Numbers in the margin indicate pagination in the original foreign text.

know the amount of soil moisture immediately on the spot. In considering such a weakness, it would be extremely convenient if a simple apparatus which can measure the amount of soil moisture immediately with some lack of accuracy could be designed. This would make it easy to measure the soil moisture all over the country.

Fortunately, recently a simple method was introduced which has been adopted at the agricultural meteorological observatory in Poona, India, and has given good results. I have experimentally built and studied an apparatus which employs a similar principle.

2. THEORY AND APPARATUS

(i) A new method for soil moisture measurement which utilizes a certain kind of thermal conductivity was presented by A. U. Momin.

In the traditional method of utilizing the thermal conductivity, a metallic plate buried in the soil is heated electrically and its temperature measured, but this method is quite troublesome. Consequently, Momin wound the latter half of the bulb of a mercury thermometer with a heating wire (this heating part is electrically and thermally insulated from the soil). Then the bulb was heated by passing a constant electric current, and the time was measured in seconds for the temperature to rise by 5° C.

The principle of this method is that, within the bulb, the half on which the heating wire is wound gains heat, while the other half — which is in contact with the soil — loses heat in a certain proportion due to the thermal conductivity of the soil.

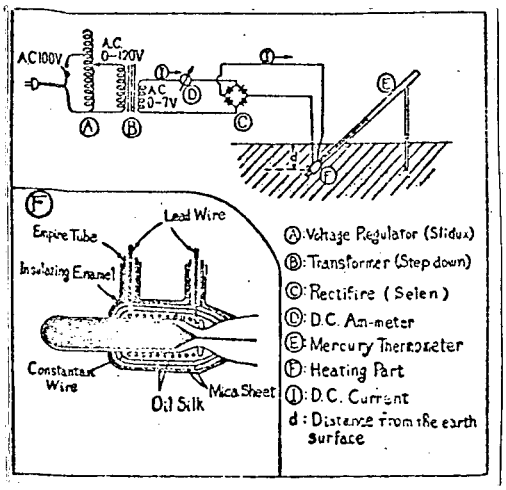

Figure 1. New apparatus for the soil moisture measurement and the section of heating part.

Because the two phenomena take place simultaneously within the bulb, the time required to raise the temperature of the thermometer by a fixed amount varies with the degree of soil humidity, taking a longer time when the soil is wet compared to when the soil is dry.

In the report by Momin at Poona, a high correlation was obtained between the time required to raise the temperature by 5° C and soil moisture measured by the weighing method.

(II) Although the essence of the Momin measurement apparatus is known, the details of the most important heating part are not clear. Thus, the author made an apparatus using a cylindrical mercury thermometer (1/5° C) shown in Figure 1.

The heating wire is a two-ply wire of enamel and constantan (S.W.G. # 38) with a total resistance of 5 ohms. The heating part is doubly insulated by sheet mica and oil silk, and an insulating paint is coated on its surface.

The source of electricity for heating can be a storage battery, but the author made an arbitrary low-voltage direct current from 100 V alternating current as shown in Figure 1 and used it. A /33
direct current "I" in the figure can be varied as required by adjusting the voltage regulator "A".

3. EXPERIMENTAL RESULTS

The following items must be determined concerning the measurement apparatus in the new method:

(A) The magnitude of the current needed for the heating part — this can be determined by studying the relation between the heating time and the temperature rise for several constant current values.

(B) The amount of fixed temperature rise — this can be determined by obtaining the relation between the heating time and the temperature rise for each soil moisture content under a constant current determined in (A).

(C) When (A) and (B) are determined, the relation between the time required for a fixed temperature rise and the soil moisture can be obtained.

Even though the item (C) is the only one which is actually needed, it can not be obtained until (A) and (B) are determined.

(I) Experiment on the Sample Soil

A small place 1 m^2 in area is specially set aside for the soil to be used in the experiment. The experiment is conducted with a new apparatus using a 2 cm deep soil which is of the volcanic ash type.

(a) The relation between the heating time and the temperature rise is a function of the heating current.

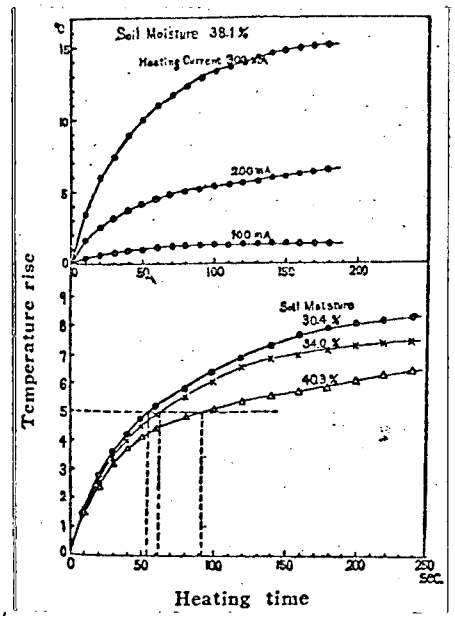

Figure 2. Relation between the heating and the temperature rise.

The first problem is to determine the magnitude of the current needed for the heating part. When the current is passed to the apparatus, the mercury within the thermometer starts to rise above the temperature within the soil. The upper portion of Figure 2 shows the relation between the heating part and the temperature rise for three values of heating current — 100, 200, and 300 mA. As can be seen clearly from the figure, at 100 mA of the heating current, the temperature rise is so small as to make it impractical for actual use. In order to minimize the measurement error, the heating time should be neither too short nor too long. Setting a temperature of roughly 5° C as a goal, 200 mA seemed to be appropriate for the author's apparatus. Thus, this value of the current is used.

(b) The relation between the heating time and the temperature as a function of the soil moisture:

Having set the heating current at 200 mA, it is necessary to determine how much the temperature is to be raised above the soil temperature. It is of course not practical unless up to 50 % of the soil moisture can be measured. The lower portion of Figure 2 shows the relation between the heating time and temperature rise for each soil moisture content. Though Momin's report has a 5° C temperature rise, the author also found 5° C as appropriate for the author's apparatus, judging from Figure 2. Thus, for the author's

apparatus, the heating time required for the temperature rise of 5° C was measured.

(c) The relation between the heating time required for the temperature rise of 5° C and the soil moisture:

If the relation between the time ('t' seconds) required to raise the temperature 5° C with a heating current of 200 mA and the soil moisture ('ω' %) measured by the weighing method at the same time is drawn in the figure, the soil moisture can be immediately found any time.

Within the scope of the soil moisture normally observed, 'ω' can be expressed as a linear function of 't', as indicated also by Momin. /34

In the experiment, the object of the study is confined to a depth of 2 cm from the ground surface where the moisture variation is large. Because of the breakage and remodification of the apparatus, the number of measured values actually obtained is small. It is shown in Figure 3. The linear relationship is as follows:

$\omega = 0.19\ t + 21.4$ error ± 2.1

ω: soil moisture in %; the measurement range: 30 to 41 %

t: heating time in seconds

the temperature of the soil: 23 to 35° C

(II) Other Experiments

The relation between the heating time required for a temperature rise of 5° C and the soil moisture shown in Figure 3 is

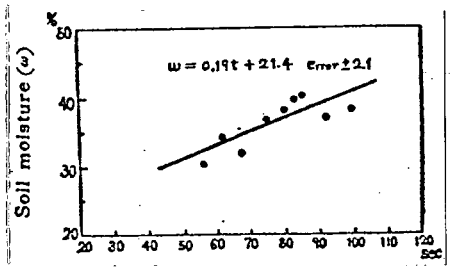

Figure 3. Relation between the heating time required for temperature rise of 5° C and the soil moisture.

naturally expected to change when the type and structure of the soil change.

As a result of studying a soil with a different structure, a different result from (I) was obtained, but the relation was again linear.

4. CONCLUSION

The measurement results from the new soil moisture measurement apparatus were not yet satisfactory due to the breakage of apparatus, in particular, the snapping of a lead wire, and the remodelling of the heating part. However, using the structure already shown, Momin's results were successfully confirmed.

When the variation in the soil temperature is large, the linear relationship shown in Figure 3 must be determined for each of at least 2 to 3 kinds of temperature range.

Furthermore, if the contact between the tip of the bulb and the soil is not perfect, an unexpected error may be created; it also becomes necessary to obtain a linear relationship for each soil where the apparatus is installed.

However, it is considered fairly convenient for routine measurements at a fixed location.

REFERENCES

1. Kusakabe, Masao. On the Method of Measurement of the Soil Moisture and 2 or 3 Measured Examples, Industrial Meteorology Study Report, Vol. 12, No. 2, 1948, p. 14.

2. Located at that time at Nishibori, Oowadacho, Kitaadachigun, Saitamaken.

3. Yamanaka, Kunitoshi. The Study of the Soil Moisture under Natural Conditions, Industrial Meteorology Study Report, Vol. 14, No. 3, 1950, p. 20.

4. Tani, Nobuteru. The Study of the New Measurement Apparatus and Experimental Techniques at Agricultural Meteorological Section of the Poona Meteorological Observatory, Agricultural Meteorology, Vol. 6, No. 1, 1950, p. 50.

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